Human Spaceflight Capabilities

Lunar EVA Dosimetry: MIcroDosimeter iNstrument (MIDN) System Suitable for Space Flight

Completed Technology Project (2004 - 2008)

Project Introduction

MIDN PROTOTYPE FLIGHT INSTRUMENT 1. Based on our experience with the MIDN development, we designed and developed an advanced version of the instrument. 2. A prototype was developed that although did not include all of the specifications was able to achieve with a 10 um thick sensor a dE/dx ~ 3 keV/um in silicon that is equivalent to a lineal energy of ~1 keV/um in tissue. BENCHTOP DEVELOPMENT SYSTEM 1. By designing and constructing a new Faraday cage that houses the sensor and preamplifier circuit, upgrading the signal transmission circuitry between the system and the data acquisition area, and designing a new data acquisition method, we were able to reduce the inherent noise level well below a keV/micron, allowing detection of the peak of the dose distributions for minimum ionizing protons, the most difficult particles to detect microdosimetrically. 2. In collaboration with the M. Sivertz and A. Rusek at BNL, we have developed a system that allows identification of incident particles, categorized them according to their mass-to-charge ratio and energy, and correlated them with individual events in the microdosimeter. Recall that our earlier work in this regard resulted in our identifying lighter ion contaminants in the beam and their contributions to the microdosimetric spectra, a fact that we subsequently learned was known to BNL personnel. 3. We measured the energy deposited in a microdosimeter with radiation beams of Carbon at 290 MeV/n and protons at 1 GeV/n, 600 MeV/n, 250 MeV/n, 100 MeV/n, and 50 MeV/n at the NSRL facility at the BNL and achieved a lower energy cutoff of < 1 keV/um in silicon equivalent to a lineal energy cutoff in tissue of < 0.3 keV/um. ADVANCED SENSOR DEVELOPMENT 1. We now have prototypes of a new design of a solid-state microdosimeter with three dimension micron sized sensitive volumes, addressing some of the shortcomings identified earlier. This sensor was developed at the Centre for Medical Research Physics, and a new grant (Australian Research Council Discovery Project) was recently received by our collaborator to further support this project. 2. We have established collaborations with the EE (electrical engineering) departments at Johns Hopkins University (JHU) to explore the potential of developing alternative silicon sensors. These new sensors will be developed as part of our follow-on grant from the NSBRI. 3. With minimal support, JHU was able to supply us with two dies that have a variety of diodes for preliminary testing. A test fixture was developed to carry out tests, and measurements of alpha particles were successfully conducted. RADIATION TRANSPORT CODES 1. We imported the radiation transport code GEANT4 and two corollary programs MULASSIS (multilayered shielding simulation software tool) and GEMAT. These Monte Carlo codes allow us to simulate the microdosimetry spectra in silicon devices. 2. We also have access to the MCNPX (Monte Carlo N-Particle eXtended) radiation transport code.

Anticipated Benefits

Microdosimetric techniques are perhaps the only experimental methods for actively determining the radiation quality of mixed or unknown radiation fields

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and their dose equivalent. Likewise, the compact nature of a solid-state microdosimeter along with its low voltage and low power consumption and remote telemetry makes such a device ideal for in-situ personnel monitors as well as area monitors. The radiation quality and the corresponding dose equivalent and/or effective doses form the basis of regulatory dose limits both in the U.S. and internationally as well as the basis for the evaluation of potential overexposures. Generally, in radiation fields with average quality factors greater than one, those radiation components with the highest quality may represent a component of the dose comparable to the dose uncertainty. For example, as the energy of x-ray therapy machines increases to accommodate intensity modulated radiotherapy and other new techniques, the contributions of secondary neutrons produced in the shielding materials to the whole-body exposure of the clinical personnel as well as the patients themselves increase. With a quality factor as high as 20, a one or two percent neutron component can contribute as much as 20 to 30 percent of the dose equivalent. Likewise, in radiation storage and clean-up, it is the dose equivalent or effective dose, not the physical absorbed dose, that determines the need and level of clean up, yet it is the physical dose that is usually measured because of the difficulty in measuring dose equivalent in the field by personnel who are not experts in microdosimetry. Finally, the detection of radiation emitted by nuclear materials that may be used in terrorist activities requires cheap, reliable, and rugged microdosimeters that can determine small changes in the radiation environment and issue reliable alerts in real time. The use of prior methods is limited in part because of the complexity, sensitivity, and lack of reliability of the most commonly used instruments, gas proportional counters. The compact system that we have developed for space applications would likewise be applicable for these situations and measurements described in the previous paragraph. We have established for the first time in a solid-state microdosimeter a lowered energy cutoff of dE/dx < 1 keV/um in silicon that is equivalent to a lineal energy cutoff of < 0.4 keV/um in tissue. Thus we have an instrument that can be used in space and terrestrially to directly assess regulatory risk.

Organizational Responsibility

Responsible Mission Directorate:

Space Operations Mission Directorate (SOMD)

Lead Center / Facility:

Johnson Space Center (JSC)

Responsible Program:

Human Spaceflight Capabilities

Project Management

Program Director:

David K Baumann

Principal Investigator:

Vincent L Pisacane

Co-Investigators:

Martin Nelson
James M Ziegler
John Dicello
Marco Zaider
Anatoly Rozenfeld
Francis A Cucinotta

Human Spaceflight Capabilities

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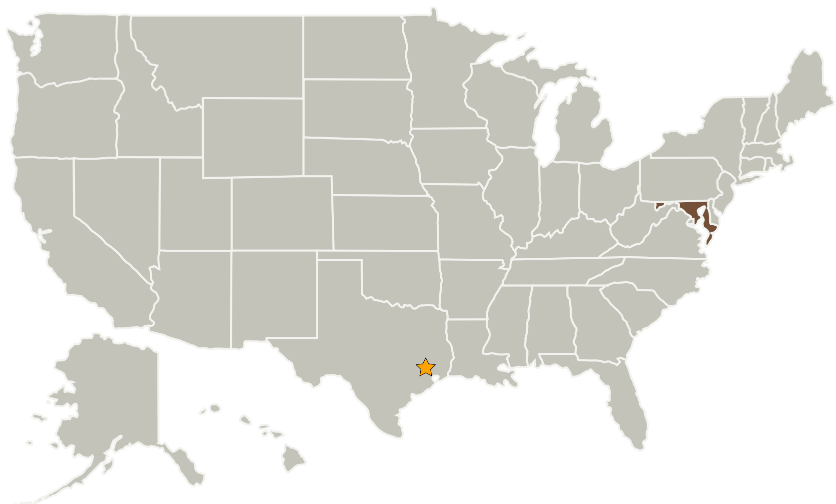
Completed Technology Project (2004 - 2008)

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Johnson Space Center(JSC)	Lead Organization	NASA Center	Houston, Texas
Memorial Sloan-Kettering Cancer Institute	Supporting Organization	Industry	
United States Naval Academy	Supporting Organization	Academia	Chester, Maryland
University of Wollongong	Supporting Organization	Academia	

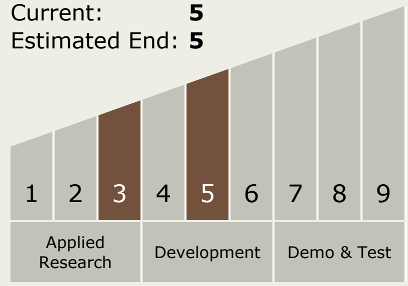
Primary U.S. Work Locations
Maryland

Project Transitions

August 2004: Project Start

Technology Maturity (TRL)

Start: **3**
Current: **5**
Estimated End: **5**



Technology Areas

Primary:

- TX06 Human Health, Life Support, and Habitation Systems
  └ TX06.5 Radiation
    └ TX06.5.5 Monitoring Technology

Target Destinations

The Moon, Mars

December 2008: Closed out

Closeout Summary: MIDN PROTOTYPE FLIGHT INSTRUMENT 1. Based on our experience with the MIDN development, we designed and developed an advanced version of the instrument. 2. A prototype was developed that although did not include all of the specifications was able to achieve with a 10 um thick sensor a dE/dx ~ 3 keV/um in silicon that is equivalent to a l ineal energy of ~1 keV/um in tissue. BENCHTOP DEVELOPMENT SYSTEM 1. By designing and constructing a new Faraday ca ge that houses the sensor and preamplifier circuit, upgrading the signal transmission circuitry between the system and the data acquisition area, and designing a new data acquisition method, we were able to reduce the inherent noise level well be low a keV/micron, allowing detection of the peak of the dose distributions for minimum ionizing protons, the most difficult p articles to detect microdosimetrically. 2. In collaboration with the M. Sivertz and A. Rusek at BNL, we have developed a syst em that allows identification of incident particles, categorized them according to their mass-to-charge ratio and energy, and correlated them with individual events in the microdosimeter. Recall that our earlier work in this regard resulted in our iden tifying lighter ion contaminants in the beam and their contributions to the microdosimetric spectra, a fact that we subseque ntly learned was known to BNL personnel. 3. We measured the energy deposited in a microdosimeter with radiation beams of Carbon at 290 MeV/n and protons at 1 GeV/n, 600 MeV/n, 250 MeV/n, 100 MeV/n, and 50 MeV/n at the NSRL facility at t he BNL and achieved a lower energy cutoff of < 1 keV/um in silicon equivalent to a lineal energy cutoff in tissue of < 0.3 ke V/um. ADVANCED SENSOR DEVELOPMENT 1. We now have prototypes of a new design of a solid-state microdosimeter with three dimension micron sized sensitive volumes, addressing some of the shortcomings identified earlier. This sensor was de veloped at the Centre for Medical Research Physics, and a new grant (Australian Research Council Discovery Project) was re cently received by our collaborator to further support this project. 2. We have established collaborations with the EE (electri cal engineering) departments at Johns Hopkins University (JHU) to explore the potential of developing alternative silicon se nsors. These new sensors will be developed as part of our follow-on grant from the NSBRI. 3. With minimal support, JHU w as able to supply us with two dies that have a variety of diodes for preliminary testing. A test fixture was developed to carr y out tests, and measurements of alpha particles were successfully conducted. RADIATION TRANSPORT CODES 1. We impo rted the radiation transport code GEANT4 and two corollary programs MULASSIS (multilayered shielding simulation softwar e tool) and GEMAT. These Monte Carlo codes allow us to simulate the microdosimetry spectra in silicon devices. 2. We also have access to the MCNPX (Monte Carlo N-Particle eXtended) radiation transport code.

Stories

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/25189)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/26000)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/24940)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/25848)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/25393)

Articles in Peer-reviewed Journals
(https://techport.nasa.gov/file/8874)

Awards
(https://techport.nasa.gov/file/25325)

Awards
(https://techport.nasa.gov/file/24965)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/24992)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/25120)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/25501)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/8797)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/8861)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/8854)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/26167)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/25514)

Papers from Meeting Proceedings
(https://techport.nasa.gov/file/24990)

Project Website:

https://taskbook.nasaprs.com